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New Approaches and Innovative Technologies to Improve Water Supply
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Chairman Inhoff, Ranking Member Boxer and members of the Committee, I am Kevin Price, Senior Science and Technology Advisor to Middle East Desalination Research Center (MEDRC) in Muscat, Oman. I am pleased to discuss new approaches and innovative technologies to improve water supply. My passion is the application of new technology to the purification of nonconventional waters to increase water supplies, reduce the risks of drought, increase jobs and standards of living, and to assist in resolving conflict around the world. I will focus my remarks on desalination and indirect and direct potable water reuse.

I retired from the Bureau of Reclamation (Reclamation) after 30 years, where I started as a researcher on the Yuma Desalting Plant and later managed water treatment engineering and research. Part of my responsibilities included managing the internal research and external research authorized by the Water Desalination Act of 1996 also known as the Paul Simon Act. My responsibilities included managing the research portion of Reclamation's water reuse program. Early in my career, I was responsible for the desalination research portion of the S&T agreement with Israel. During one of my trips, I was asked by a television reporter why someone from the U.S. was attending the Israel Desalination Society meeting. I explained that the problems and solutions Israel was currently solving would be important to the U.S. as it faced similar problems in the future.

I currently work for MEDRC which is an international institution created in 1996 as a part of the Middle East Peace Process and is hosted by the Sultanate of Oman. Members of MEDRC include the Palestinians, Jordanians, and Israelis as well as the U.S Department of State. Part of my duties as a Reclamation employee was helping in the design and implementation of MEDRC. MEDRC works to address two grand challenges: water and peace. This is done through capacity building in training and research.

There is an important technical distinction that must be made before proceeding with my testimony. Water purification means a number of things depending on the audience. Regulatory frameworks around the world describe what needs to be removed from water and to what levels. For many, this means removing suspended particles, bacteria, viruses, and very large molecules generally through helping the particles to stick to each other followed by filtration. This will not work with many nonconventional sources, because a major portion of the contaminants is dissolved, not suspended as particles in the water. Desalination or the removal of dissolved materials is a fundamentally different process than filtration. Desalination is also a critical component of indirect and direct potable water reuse.

Conventional water treatment was described as early as 2000 BC with very simple municipal treatment beginning in the early 1800's. Chemical treatment with coagulation/flocculation and chlorination started in the late 1800's and early 1900's. Comprehensive regulations and standards in the U.S. weren't developed until the 1970's. Today, treatment can be to standards better than drinking water quality (think microelectronics, pharmaceuticals, boiler feedwater), which allows us to treat to the intended use. No longer is it necessary to think of drinking water, wastewater, and other impaired water as separate entities; they are all water waiting to have the containments removed. Among the 21st century technologies are: microfiltration (MF); ultrafiltration (UF); reverse osmosis (RO); membrane bioreactors (MBR); electrodialysis reversal (EDR); thermal processes including multistage flash (MSF), multi-effect distillation (MED), vapor compression (VC), humidification/dehumidification; capacitive deionization (CDI); closed circuit desalination; solvent extraction; forward osmosis (FO); pressure retarded osmosis (PRO); reverse electrodialysis (RED); membrane distillation (MD); adsorption, ion exchange, advanced oxidation; and others. Many of these technologies depend on separations driven by pressure, electrical attraction, heating/freezing, adsorption, and incremental improvements in existing technology. Another important opportunity in the 21st century is information driven technology ranging from optimization of treatment facilities to information on the quality, quantity, and individual use of water resources.

It is important to acknowledge the role the U.S. government played in the development and maturation of these technologies starting with the Saline Water Act of 1952. The Office of Saline Water and later the Office of Water Research Technology in the Department of Interior operated from 1952 through 1982. In 1952, seawater desalination cost $34 per thousand gallons compared to today at $2 to $4 per thousand gallons. There were demonstration facilities in New Mexico, Texas, South Dakota, California, and North Carolina looking at different technologies for brackish and seawater desalination. A number of companies were spun off from the program. From an investment of over $2 billion in todays dollars, over 1200 research reports were generated describing new findings. During this period electrodialysis was commercialized; significant improvements were made to thermal desalination; new knowledge was developed in materials and physical chemistry; membranes were created and commercialized; large-scale demonstrations were carried out; and large-scale designs were completed although never built. In 1965, the first international Symposium on Desalination was hosted in Washington, DC and chaired by the Secretary of Interior, Stewart Udall.

So where are we today? Statistics from Miriam Balaban the Founder and Editor in Chief of several desalination journals show the decline of research papers from the U.S., since the days of U.S. government support. For the period of 1966 to 1975, 539 papers were published from around the world with 235 or 44% coming from North America. For the period 2009 to 2013, 5884 papers were published from around the world with 242 or 4% coming from North America. The biggest increases were for the Asia Pacific region with 42% of the total, Europe with 26%, and the Middle East with 18%. The increase in papers coincides with the increased funding for desalination research from Singapore, Korea, Japan, China, Australia, Israel, the Gulf States, and Europe.

The research investments in other parts of the world were for a number of reasons. In some cases, it was for national security so a nation would not be dependent upon an unfriendly, or even a friendly neighbor, for their water supply. Some countries are seeing increased drought due to climate variability. In other cases, it was to support improved efficiency and to reduce future costs of the large investments already made in desalination and reuse facilities. Then there are the countries who have combined a national need with the opportunity to expand their new capabilities into the international market for their private sector. Many of these technologies are built on membrane separation that was invented in the U.S.

Before discussing some of the lessons learned in Israel and how the U.S. can pursue innovation, advanced water treatment is the most expensive alternative. By definition, it takes energy to remove impurities from water. All countries must look to conservation, managing leakage, appropriate pricing, recycling, management of water for agriculture, which are less expensive, less energy intensive, and more environmentally friendly. This does not mean that desalination should not be a component in a balanced water portfolio. Desalination balances the risks of depending wholly on sources affected by drought, climate variability, or non-sustainable groundwater supplies.

The lessons learned in Israel have consequences for the U.S. especially in drought plagued areas near the sea. Israel's water supplies have been limited from it's creation. They have had to learn how to conserve through public education, reducing water losses, and appropriate pricing. Because the need for new sources was so immediate, they knew the technology already would work and decided to move forward using desalination without perfect information. They had good knowledge from the experience of others on how to manage the environmental effects of desalination such as reducing chemical addition, reducing entrainment and impingement of intakes, and mixing of the outfall concentrate back into the ocean. In discussing this with Oded Fixler, the Deputy Director General of the Israel Water Authority, he said that technology is only technology and already works. The real issues are broader such as who owns the water, the cost of water, whether or not the cost is appropriate for crops and which crops, and who will subsidize. By developing desalination as a part of their integrated water resources, Israel was able to develop an industry that can now compete internationally. I found it interesting that Israel has removed a significant amount of bureaucracy by centralizing control over water resources. One outcome of this is one set of municipal water prices for the country. Previously, Mekorot delivered water to the cities and then each city sold the water. In some cases, water prices were used to fund subsidize municipal programs. It is important to note the differences between Israel and a state like California. Not only is the control of water highly fragmented in California, the state is much larger than Israel. Israel has a population of around 8 million in 8 million square miles. California has a population of around 39 million in 163,600 square miles. The opportunities to move water throughout the country are much greater than in California.

The broad goals of an advanced water treatment research program supporting innovation should be: (1) to lower the financial costs of desalination so that it is an attractive option relative to other alternatives in locations where traditional sources are inadequate, and (2) understand and reduce the environmental impacts of desalination and develop approaches to minimize these impacts relative to other water supply alternatives. Much more information on this can be found in the 2008 National Academy of Sciences report, *Desalination*.

Innovation in desalination and advanced water treatment should follow a progression related to risk taking and project size. The Water Desalination Act of 1996 is a good example describing this progression needing one or two updates. Research funds should be available for basic research encouraging experts from other fields who may never have thought about purifying water at the molecular level. The next stage is in the laboratory where conditions can be controlled and factors that influence the process can be studied and modeled. Once the laboratory or bench scale stage is successful, it is necessary to carry out pilot scale testing in the real world at a test site. Many factors that might influence the process can only be studied under real conditions. Once pilot scale testing is successful and before building a full scale facility, a demonstration facility should be tested. The size of the demonstration scale may be one or two orders of magnitude smaller than full scale. While this is more expensive than the earlier stages, it is less expensive than full scale and helps to mitigate the risk of being the first ever tested. The demonstration scale also allows bringing in a local utility, a local engineering firm, a local university, various vendors interested in the new technology, the local politicians, and the regulators. While a demonstration mitigates risks it also provides for capacity building, public outreach, and acceptance. Throughout the research progression, investments have to be made to streamline technology transfer to ultimately commercialize the process.

One new tool not in the Desalination Research Act of 1996, that is gaining a lot of attention and success, is the use of crowd sourcing. While the use of challenges and prizes is not new it is receiving a significant amount of renewed attention in advanced water treatment. The expectation is someone who may never have heard about advanced water treatment has a new solution and is motivated to compete for a prize.

To end my testimony, I will list the lessons learned by one of the most experienced desalinators in the business, Dr. James Birkett in *Desalination at a Glance* published by the International Desalination Association, and lessons I learned with my colleagues while working at Reclamation.

- It will be simple and must be capable of high throughputs.
- It will be fast. The time the feed water stays in the system must be short and is on the order of seconds for reverse osmosis. Because rivers of water are being treated, slower process mean more equipment and greater cost.
- It will operate at high recovery. This means a large majority of water entering the treatment system leaves as purified water lessening the volume of concentrate and reducing the amount of water being pumped through the system.
- It will be reliable. The size of the plant has to be increased to account for when it is not operating leading to higher costs. If storage of purified water is limited it is even more important to minimize outages.

Some of the lessons I learned with my colleagues while I was at Reclamation:

- Institutional/political needs create significant technical opportunities,
- For generating innovation, unsolicited proposal requests with broad boundaries generates unexpected ideas/proposals,
- Consistent funding at low levels is better than higher levels of inconsistent funding,
- It is imperative to have strong initial and periodic technical reviews combined with freedom to accept risk when studying the unknown,
- Outside advisors and reviewers of a program are essential to assist in testing ideas, bringing diversity of experiences and ideas,
- If research is to solve problems and meet needs, a strong technology transfer program must exist to pull innovations from the laboratory into use,
- When moving technology to rapid implementation, demonstration provides the opportunity to involve all affected parties at an early stage.